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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Gear Lubrication

PUBLISHED MONTHLY BY
THE TEXAS COMPANY, U.S.A.
TEXACO PETROLEUM PRODUCTS

"The Graveyard of Gears"

—An actual photograph made in a junk yard

Nine Out of Ten that End Here go because of Faulty Lubrication

IT is a conservative estimate that but one out of every ten gear teeth carries a theoretically correct film of protective lubricant. Yet, lubrication is the Guardian Angel of the gear tooth. Without it the "graveyard of gears" will claim an astounding number of victims.

The essence of effective gear operation is the reduction of sliding friction. Gear teeth are designed by scientists, cut by master-craftsmen, and installed by specialized mechanics. The ideal is to attain purely rolling motion between the teeth.

Initial success is readily attainable.

But, the secret of continued success is lubrication. Without that protective film the gear teeth will suffer. Science cannot prevent this by design, construction or installation. It is a practical matter of selecting the right lubricant to meet the operating conditions involved.

As an aid we have prepared a chart of Texaco Gear Lubricants. (See last page.) We commend it to your careful attention and study. We feel sure you will profit thereby.

Furthermore, if you are operating under especially severe conditions, don't hesitate to tell us of your troubles. Texaco Engineering Service is available to insure your peace of mind, and increase your production through the practical application of Texaco Lubricants.

THE TEXAS COMPANY, U. S. A.

Texaco Petroleum Products

Dept. H, 17 Battery Pl., New York City

Atlanta	Dallas	Houston	New Orleans	Oklahoma City
Boston	Denver	Jacksonville	New York	Philadelpnia
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Gear Lubrication

IN the development of industrial machinery, one of the outstanding accomplishments has been the application of the basic principles of transmitting motion to all manner of ingenious process mechanisms. To the creative ability of the engineer is due all credit for this transition from an age of manual labor to an era of mechanical production which even the most original of us would have hesitated to forecast but a decade or so ago. Certain of these almost-human machines, such as the newspaper press, the glass bottle machine, the jacquard motion (in the weaving of textiles), the paper machine, etc., have been discussed in previous articles in LUBRICATION in connection with their respective industries.

To read about them is to wonder. To study them in operation, as has been our good fortune, is to marvel. Perhaps an attendant hovers here and there to lubricate or adjust certain wearing parts. But more commonly will these machines function absolutely automatically as long as power is supplied and raw product is fed to them, the only labor necessary being perhaps involved in changing this latter or removing the finished goods.

An analysis of their operation, however, reveals a remarkable similarity. There are comparatively few basic operating principles involved, as, for example:

1. The transmission of motion by gearing, chain mechanism, belting or rope drives.

2. The application of bearings for the accomplishment of rotary or reciprocating motion with the least expenditure of friction, and

3. The use of cams or irregular surfaces for the purpose of converting rotary motion into oscillating or reciprocating motion.

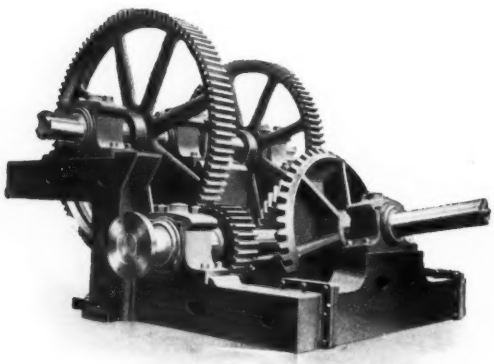
All of these have been discussed in brief in connection with practically every article which has appeared in LUBRICATION. But with the exception of Driving Chains,* none have been treated in detail, to analyze the basic principles of mechanics involved and bring out the extent to which effective lubrication makes possible the accomplishment of their purpose with the least expenditure of power in overcoming the friction which is the inevitable result of motion between any two solid bodies.

Hence this article on gears, their types, principles of design, and lubricating requirements. Essentially, gears will consist of circular discs, wheels or shafts, the surfaces of which are notched or cut out to form a series of very accurate teeth which are designed to mesh with other teeth of similar pitch or shape, which are cut on other gears, or perhaps on a straight surface to form what is known as a rack. As a rule, gears will be so much larger, comparatively speaking, than other wearing parts on the average machine that very often the impression will be gained that their relatively massive construction warrants but little attention from a lubricating point of view. As a result, the practice is all too-prevalent to ignore them or merely daub the tips of their teeth with dirty waste oil and forget them—though never forgetting to complain about their noisy operation.

Gear lubrication, however, is one of the most important factors in machine operation today.

*See LUBRICATION, August, 1923.

It involves more than the mere prevention of wear or elimination of noise. It ties directly back to production. In other words, noise is nerve-racking, and wear may some day require replacements; but back of all this is the development of inaccuracy, which, to the progressive, industrial engineer, is an unpardonable fault in a machine. Then, as to the matter of power consumption; it is surprising how much power can be unnecessarily wasted as a result of neglect and a lack of appreciation of the fact that gears are in general quite as accurately designed as any other machine details. Furthermore, faulty gear operation which may be the cause of shutdowns, stripped teeth, etc., may frequently involve considerably more serious difficulties than worn cams, chain links or bearings. As a rule, these latter can be taken up or replaced in an hour or two, according to the extent to which they have been damaged. Stripped gear teeth, however, or the occurrence of uneven wear which may have materially altered the pitch, will require replacement, and replacing of gears is a serious item on any piece of machinery today.



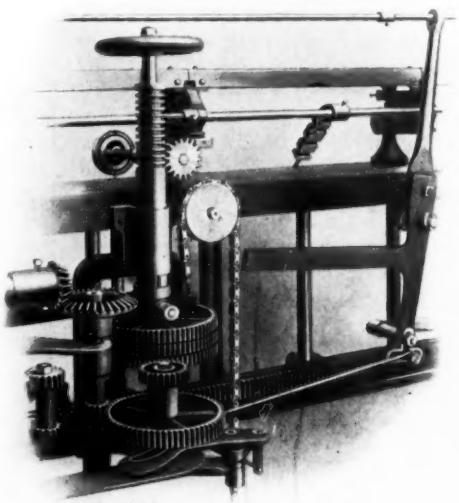
Courtesy of Poole Engineering & Machine Co.

Fig. 1.—An arrangement of spur and bevel gears, showing the extent to which direction of motion can be altered by means of such mechanisms. Note massive construction of bearings and supports.

THE ADVANTAGES AND PURPOSES OF GEARS

Wherever it is desirable or necessary to eliminate power losses through excessive lost motion gears will be found to be of distinct advantage. As a result gears are used to supplant such methods of power transmission, as friction wheels, and belt or rope drives, within, of course, reasonable limits of distance. Theoretically it would be perfectly feasible to build a train of gears over any distance. Practically, however, this would be an economic impossibility, due to the expense and amount of material which would be involved. Therefore, while gears are an ideal means of transmitting motion, they cannot always be resorted to. In the transmission of power by means of gearing we should theoretically only be involved with pure rolling motion between the surfaces of the gear teeth as they pass into and out from mesh. On the other hand, it is practically an impossibility to attain this ideal, and regardless of the accuracy with which the teeth may have been cut, there will occur a certain amount of sliding motion. Perhaps this is one reason why so many of us are prone to regard gear lubrication as of but little consequence, figuring that the greater proportion of the motion involved will be rolling. We must not forget, however, that sliding motion will impose considerably more wear on the gear teeth than will rolling motion. Furthermore, as wear continues to occur more and more will rolling motion be supplanted by sliding motion.

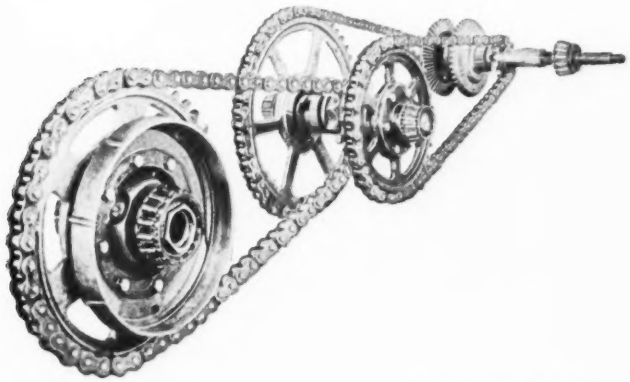
As a result, it is evidently erroneous to regard gear lubrication as a matter of apparent unimportance. Furthermore, we must take into account the fact that whatever the nature of the friction involved it will depend to a considerable extent upon the alignment of the gears, the accuracy of their cutting and the freedom of movement with which their teeth engage or mesh. Under ideal conditions, the teeth should roll so smoothly into each other and with such a constant relation in velocity between their respective surfaces that this friction will be reduced to a minimum. In this connection the



Courtesy of Woonsocket Machine & Press Co., Inc.

Fig. 2.—An example of the extent to which gearing of various types can be applied to industrial machinery. This device for regulating the tension of roving in the cotton mill includes spur and bevel gears, a chain drive and a rack and pinion mechanism.

lubricant, if it is properly prepared and carefully applied, will play an important part in the reduction of noise, the elimination of vibration or chattering between the teeth and the prevention of abnormal wear.



Courtesy of Link-Belt Company.

Fig. 3.—The sprockets which are a necessity to a driving chain installation, are essentially spur gears or toothed wheels. Note also the tapered roller bearings.

According to the results which they bring about, gears can be grouped into three distinct classifications, i. e.,

1. For the transmitting of power from one point or element in a machine to another, either in the same plane or in planes at an angle with each other.
2. To bring about changes in speed, as, for example, in the transmission case of an automobile, or in the reduction mechanism of a marine steam turbine.
3. For the changing of directions of rotation, as, for example, in the rolling mill in a steel plant, or wherever it is essential to change the point of application of power in a simple or direct manner.

TYPES OF GEARS

According to the specific functions which they are intended to perform, gears will vary extensively in regard to their design, construction and principles of operation. Broadly speaking, the term "gearing" is implied by many as including any form of device designed to function or transmit motion as mentioned heretofore. As a result, we should group friction, chain and screw mechanisms under the broad caption of gearing. The theoretical accuracy of this assumption may be questioned by some. Be that as it may, it is only mentioned as a point of interest, for in this article our chief concern will be with those several designs of tooth mechanism which are more commonly understood and employed as gears.

Industrial gears will in general comprise circular mechanisms which rotate around the same axis as the shaft or drum on which they are cut or attached. The peripheral line of their teeth, however, is not necessarily cylindrical; it may be conical as in the case of bevel gears. Furthermore, it is possible to extend this idea of tooth mechanisms to a flattened surface, as in the case of a rack and pinion, although one element—the pinion—must be circular in the form of a standard gear or worm. The function of a rack and pinion device is essentially to bring about reciprocating motion by virtue of the very nature and limitations of the toothed rack.

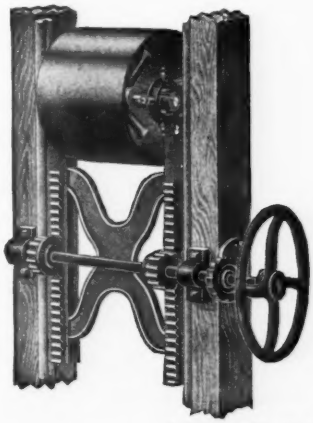
For the purpose of identification and further discussion, it is deemed advisable to itemize circular gearing according to trade standards, i. e.,

Spur
Spiral or Helical
Bevel or Angular
Annular
Worm

Each will be distinctive according to the manner in which the teeth are cut, the general appearance or shape of the gear and the axial direction in which the motion is to be transmitted.

Spur Gears

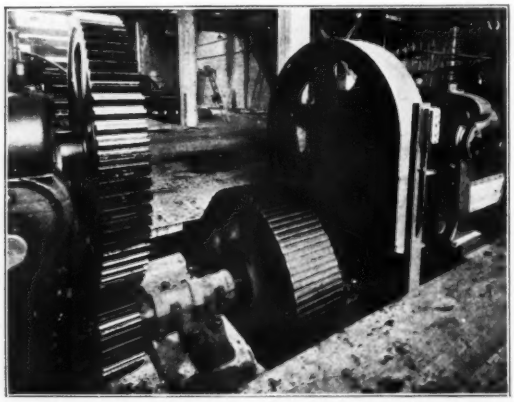
Gears which comprise a cylinder, disc or wheel with teeth cut thereon in parallel and each in a common plane with the axis, are known as spur gears. Their essential purpose is to transmit motion from one parallel shaft to another. The direction of rotation will, of course, depend on the number of such gears involved in the train. With an even number motion will be reversed: in other words, the direction of rotation of the last member will be



Courtesy of The Medart Company.

Fig. 4.—A rack and pinion belt tightener. This can be installed either horizontally or vertically.

opposite to that of the first. An odd number of gears, or the use of intermediates as they may be called, will serve to bring about the same direction of rotation in the driven gear as exists in the pinion or driver. The use of intermediate gears for the purpose of bringing about certain directions of motion, or the operation of intermediate shafts, will have no effect upon the relative speeds of the driving and driven gears.



Courtesy of Morse Chain Company.

Fig. 5.—An example of chain drive and spur gearing in use on the same unit. Here the lubricant is applied by hand therefore care must be exercised in obtaining products of the requisite viscosities.

Spur gears are very extensively used on a great variety of industrial machinery where medium tooth pressures and average speed conditions are involved. According to the type of service, they may be built encased or exposed. As a rule this will depend upon the extent to which foreign or abrasive matter would be present, or the requirements as to safety. As a rule gears should be guarded, but whether or not these guards are oil-tight is another matter. Oil-tight casings permit of bath lubrication and this in turn insures the utmost protection of the teeth, provided the oil is of a body or viscosity commensurate with the pressures involved. On an average a lubricant in the neighborhood of 100 to 200 seconds Saybolt viscosity at 210° Fahrenheit, will be best for bath-lubricated gears.

Under exposed conditions, however, a heavier product will be necessary for the lubricating film must be capable of adhering tenaciously to the teeth (for the period of application is relatively infrequent), resisting temperature changes, and the effects of speed and centrifugal force which would tend to throw off the lubricating film. Naturally the occurrence of this latter, might leave the teeth in a condition conducive to wear, and also, the product passing through the machine might be seriously damaged through contact and "oil spots."

Spiral or Helical Gears

Under this classification will be included all gears of a cylindrical nature which have their teeth cut on an angle or in helical form. They, like spur gears, are generally used for the connection of parallel shafts, although it is possible to design them in the form of bevel gears. In appearance the teeth on such gears are twisted or helical with respect to the pitch surface.

The arrangement of teeth in this manner is claimed to give greater strength and smoothness of action than can be attained with ordinary spur gears. On the other hand, they develop end thrust along the shaft and therefore necessitate the use of some type of thrust bearing to take care of this. The "herringbone" type of helical gear, however, eliminates this thrust by virtue of having its teeth cut to slope in opposite directions. It is therefore advantageous for use in speed reduction mechanisms, as in certain steam turbines, where thrusts of this nature must be eliminated as far as possible. Furthermore, with herringbone gears wear occurs in such a manner as to develop rolling motion almost entirely, the occurrence of sliding friction being practically negligible.

The lubricant on a herringbone gear performs an especially important function as a noise and vibration eliminator. In fact, the reduction of vibration is equally as essential as the maintenance of a lubricating film. On gears of this type vibration or rattling, due to imperfect adjustment, uneven operation, or an insufficient film of lubricant, is claimed to promote pitting

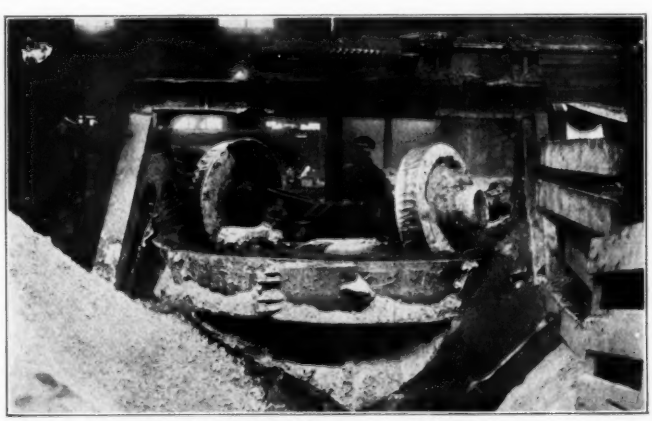


Fig. 6.—A bevel gear drive attached to a grinding mill. Here the lubricant must possess a high degree of adhesiveness for it must effectively protect the teeth from dust, dirt and other detrimental elements.

along the pitch line. This will be especially true if the gears are not properly aligned, or if cutting of the teeth has not been properly done. Once such pitting has begun certain authorities claim it will tend to become cumulative or occur to a considerable extent, oftentimes causing the formation of metallic scale. When this latter ultimately breaks off, as it probably will under extreme conditions, the corners of the teeth would be rounded off and the pitch materially altered.

To prevent such pitting effective lubrication is therefore essential. Inasmuch as internal friction must be as low as possible, a relatively fluid lubricant is preferred by many operators. Herringbone gears generally run in a bath of lubricant or are equipped for force feed lubrication as is the case with reduction-geared turbines. Here, as in certain other types of installations, it is frequently essential and desirable to use the same grade of lubricant on both gears and the adjacent bearings. For this purpose an oil of from 300 to 750 seconds Saybolt at 100° Fahrenheit will usually be preferred, depending on the intensity of operation, class of service and size of gears. On the other hand, where herringbone gears are bath lubricated it may often be more satisfactory to use a heavier-bodied product, especially on larger installations. Here the viscosity range may vary from 100 to 200 seconds Saybolt at 210° Fahrenheit. A similar grade of straight mineral lubricant will generally be applicable to plain, helical or spiral gears, especially where provision is made for lubricating the thrust bearing independently.

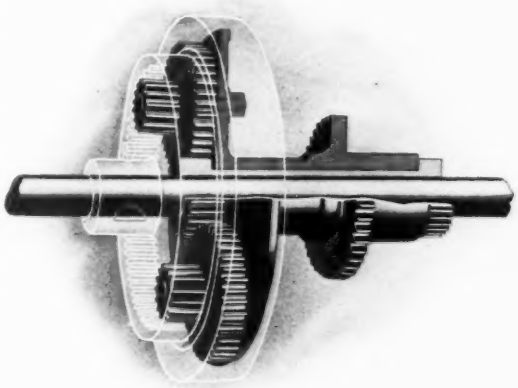
Bevel and Angular Gears

But all externally-cut gears are not provided with non-intersecting axes. In other words, motion must frequently be transmitted at an angle within the same plane. Where this latter is a right angle the gears are called beveled; otherwise, they are termed angular gears. They will involve gears on which the teeth are cut on an angular surface such as would be represented by a truncated cone. In turn the size and relative speeds of the gears is used to further identify them. That is, gears of the same size are known as mitre gears, whereas if the size is unequal they are termed angle reduction gears.

From a lubricating point of view, such gears, as a whole, will differ but little from spur gears. practically the only difference will be in regard to the relative amount of sliding and rolling motion which will occur. As a rule there will be more of the former than with other types of gears, due to the frequently greater difficulty involved in the accurate cutting of teeth and alignment of the respective shafts. To meet these possible difficulties it is oftentimes preferable to use a somewhat heavier lubricant, which will furnish a sufficient film to not only take up any shocks involved, but also capable of resisting the wiping effects of sliding motion.

Annular Gears

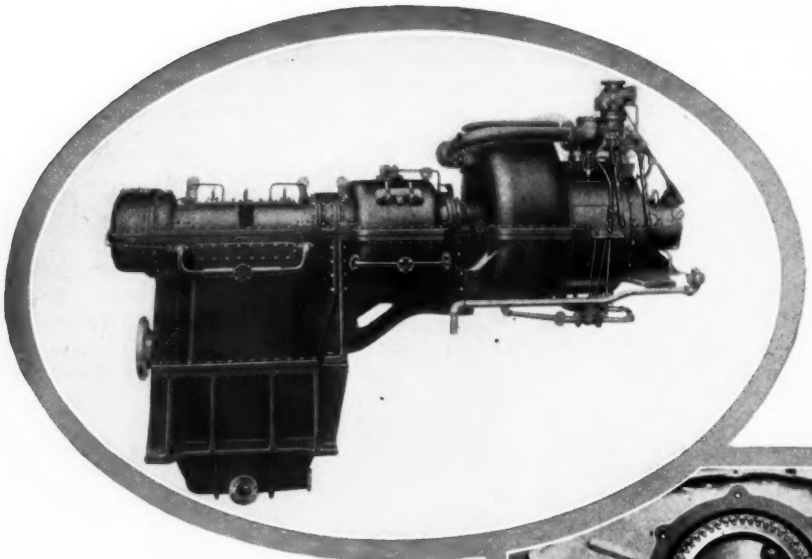
Where a circular gear is built with its teeth cut over the internal instead of the external surface it is known as an Annular Gear. In general these teeth are cut in a similar manner to those on spur gears. The companion gear or pinion, however, must, of course, be a standard type of spur gear, with teeth cut to the proper pitch to mesh with those on the annular. Annular gear installations are adaptable for relatively large speed reductions, where the direction of rotation is to be reversed. Typical examples of their usage are the main driving elements of certain tractors, and the reduction mechanisms on some types of textile roving frames.



Courtesy of Woonsocket Machine & Press Co., Inc.

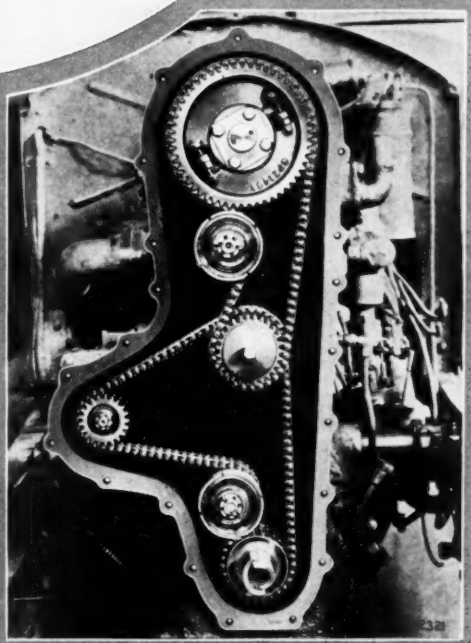
Fig. 7.—Showing in detail how an annular gear arrangement can be built in connection with other gears of the spur type.

In their lubrication annular gears involve much the same conditions as do spur gears. In fact, where they operate exposed, practically the same grades of straight mineral semi-fluid lubricants as would be required on exposed spur gears will be applicable. The effect of centrifugal force on an annular gear, however, is naturally the reverse of that on a gear with externally cut teeth. Hence, there will not be the same tendency for the lubricant to throw off, except as it is taken up by the spur teeth of the driving pinion. Certain installations on the other hand will be designed for bath lubrication. Here, of course, a lighter, more fluid oil, commensurate with the pressures and size of the teeth, can be used effectively.



Courtesy of General Electric Company.

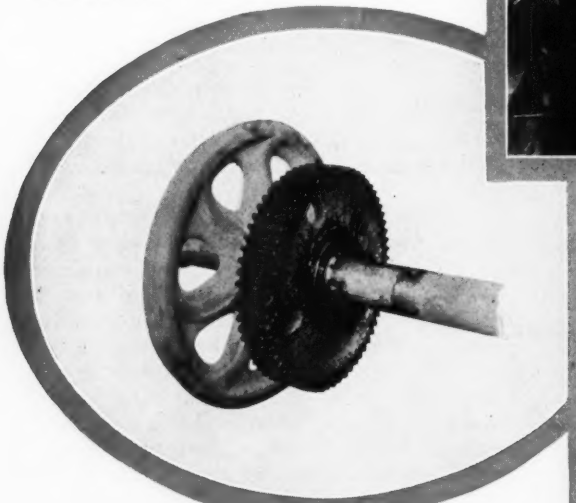
Fig. 8 (*above*).—A steam turbine and reduction gear housing.



Courtesy of Link-Belt Co.

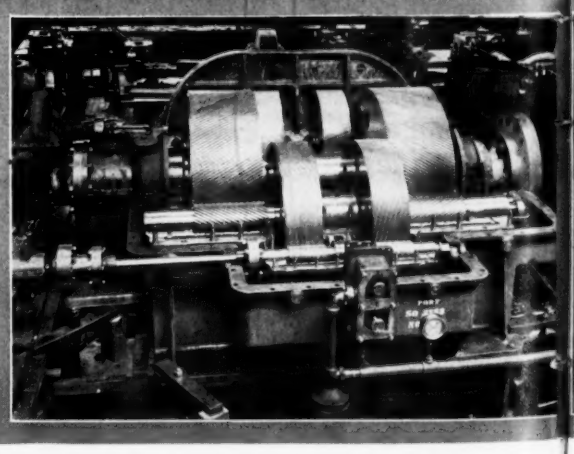
Fig. 9 (*right*).—A front end silent chain drive. Note relation of chain links to gear teeth. Such chains and gears can be readily oiled by the engine lubricating system.

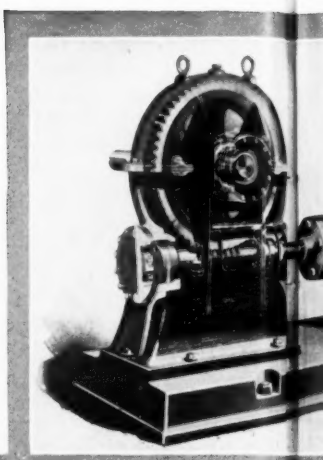
Fig. 10 (*below*).—A trolley car gear. Note proximity to wheel. Although enclosed such gears are frequently exposed to dust, dirt and water. Hence the need for careful lubrication.



Courtesy of Westinghouse Electric & Mfg. Co.

Fig. 11 (*right*).—Exposed view of a herringbone reduction gear mechanism showing relation of teeth of gears and pinions.





Courtesy of The Cleve

Fig. 12 (*above*). A moto reduction gear. Ne the the worm. This lu ca sary lubricant to t gear

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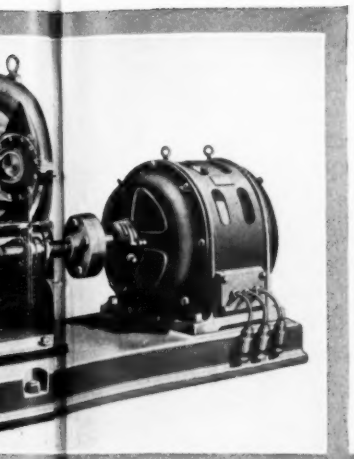
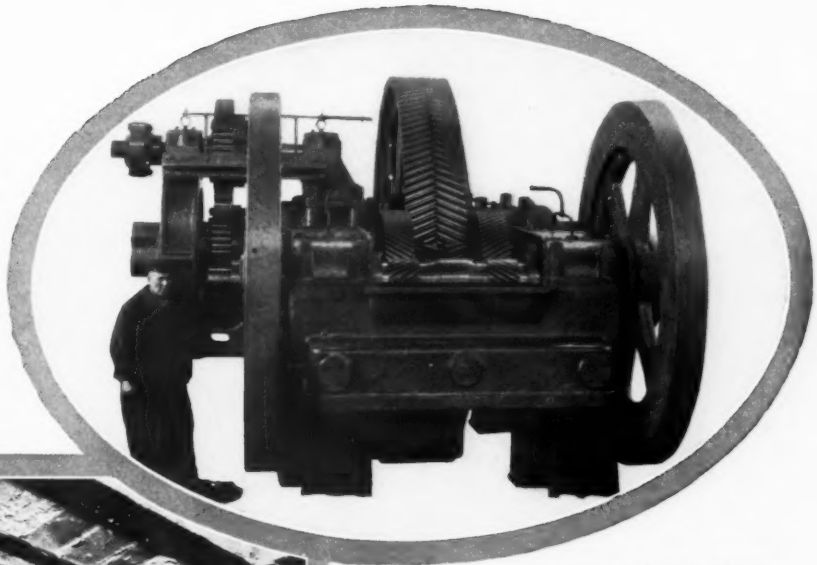


The Cleveland Worm and Gear Co.

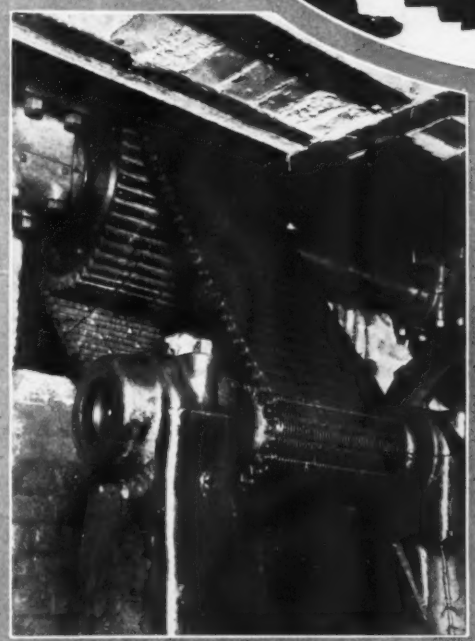
(*above*).—A motor-driven worm gear. Ne the oil bath below This ter carries the neces- cant to t gear teeth above.

Some Typical Gear Installations



Courtesy of Falk Gear Company.

Fig. 13 (*above*).—An arrangement of herringbone reduction gears with a spur gear connection to the left.

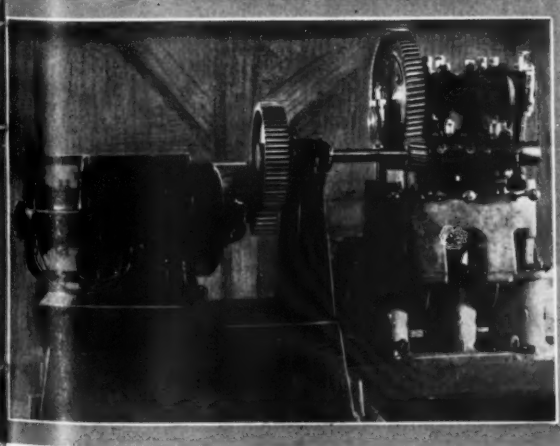


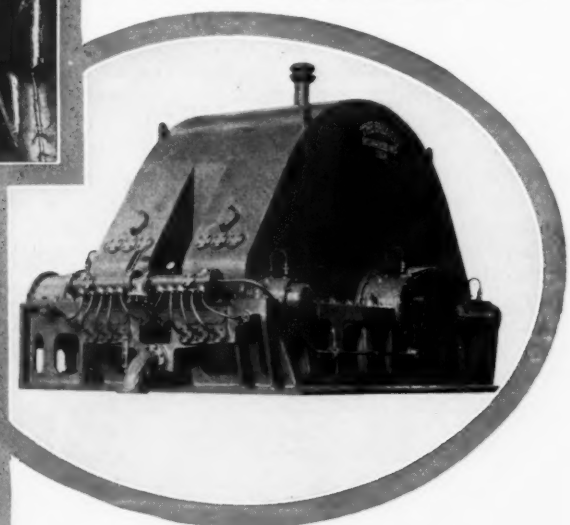
Courtesy of Morse Chain Co.

Fig. 14 (*left*).—A modern chain belt installation. Note the size of the chain and the massive construction of the gears or sprockets.

Courtesy of Falk Gear Company.

Fig. 15 (*below*).—A reduction gear case showing oil piping, manifolds and connections. Gravity or pressure lubrication are used on many such installations.



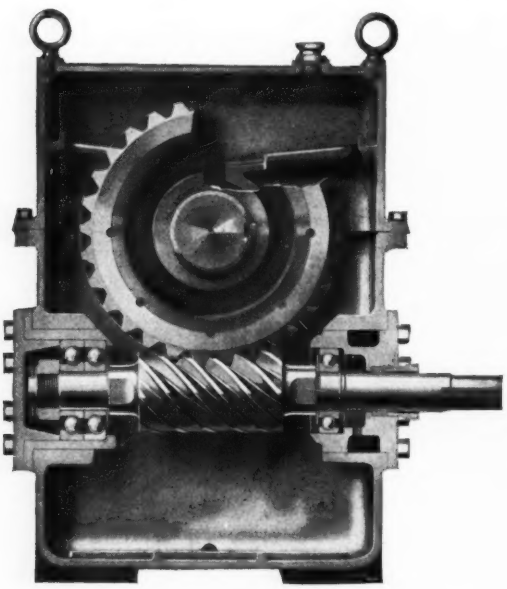


Courtesy of R. D. Nuttall Company.

Fig. 16 (*left*).—A spur and helical gear drive attached to a vertical pump.

Worm Gears

Where motion is to be transmitted between two non-intersecting shafts, located at right angles to each other and not in the same plane, a worm and gear installation is applicable. This involves a worm gear which is a cylinder, on the surface of which is cut one or more continuous helical teeth, which more or less extend round and round over the entire length. The worm is usually the driving element. Its companion mechanism is a helical type of gear. The entire mechanism is extensively known as a worm reduction gear.



Courtesy of De Laval Steam Turbine Co.

Fig. 17.—Section through axis of worm shaft of a modern worm reduction gear. Note the forward and rear worm shaft bearings of the radial ball type. Lubrication of this entire mechanism is automatic, the oil thrown from the gearing being caught in troughs, as shown, to be led to the bearings in sufficient volume to provide ample lubrication.

A device of this nature is especially suited to conditions requiring a comparatively high speed reduction ratio with a minimum of gears. Properly constructed it is claimed to give exceptionally silent operation and high efficiency. It is compact, can be readily equipped with an oil-tight housing, and can be installed in locations which might often prohibit other types of drives. Due to the manner of housing, worm reduction gears can generally be bath or splash lubricated. Operating and constructional conditions, however, will require a relatively wide variation in the viscosity of the lubricant. In certain instances, for example, a gear lubricant of approximately the viscosity of a mineral steam cylinder oil will be required. In others a machine oil, of from 300 to 750 seconds Saybolt viscosity at 100° Fahrenheit will suffice. Essentially the problems are to maintain the requisite film of lubricant on the gear and worm teeth; to reduce the starting and operating torque as far as possible; and to lubricate the shaft bearings with a minimum of frictional resistance. Ball and roller bearings are extensively used in such installations, especially for the worm shaft, and for the purpose of taking up end thrust. Now, anti-friction bearings of this nature should be served with as low a viscosity lubricant as possible, for essentially the function of this latter is to protect the highly polished surfaces rather than to lubricate. So a compromise will often be necessary, especially when the one lubricant must be used throughout the gear set.

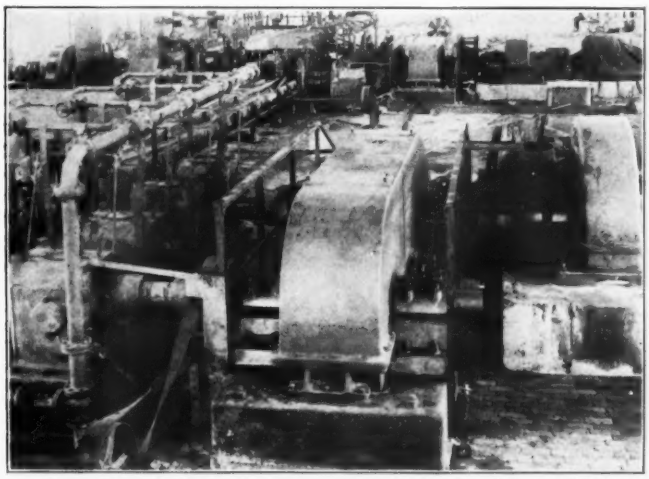
Where such gears are bath lubricated the level of the oil is of decided importance. We must remember that the development of "drag" or excessive internal friction may become a decided factor in the matter of power consumption. So as a rule the oil should be carried at such a height as to insure suitable dipping of the teeth of the lower element; submergence of too much of either the gear or worm is not advisable. Usually provision will be made for distribution of the lubricant via the teeth of the gear to the respective shaft and thrust bearings, or else these will be provided for external or independent lubrication. Where the worm is located below the wheel or gear, the oil lever should usually be carried at the center line of the worm shaft. Where the worm is above the gear, however, the problem may be more difficult, for the gear teeth will carry less lubricant to the worm than this latter would to the gear teeth. So a heavier, more adhesive lubricant may often be necessary, or the level of the lubricant may have to extend considerably above the lower-most teeth of the gears.

Whatever the viscosity of the lubricant, "oiliness" or an ability to adhere and lubricate with a minimum of fluid friction, and low pour test are the essential requirements. This latter should be as low as possible, otherwise under colder operating conditions congealment may occur, especially when the gear set is idle, with the result that insufficient lubrication and high power consumption may result.

SELECTION OF GEAR LUBRICANTS

Having gained an insight into the lubricating requirements of the predominating types of gears in use today and noted wherein each type differs from the other we are now in a position to study the matter of the selection of suitable lubricants. There are certain definite properties which such products should in general possess if they are to function effectively, i. e.

1. Sufficient lubricating ability or "oiliness" to insure the reduction of both solid and fluid friction to a minimum.
2. A viscosity commensurate with the method of lubrication and the amount of heat that may be encountered, such that a suitable film will be insured between the teeth as they become enmeshed, and the effects of both pressure and temperature resisted. Pressure, of course, exerts a squeezing out action; temperature renders a lubricant more or less fluid according to its degree, for viscosity is reduced as temperature rises.
3. A sufficient degree of adhesiveness so that in event of use under exposed or semi-enclosed conditions a requisite film will remain on the teeth to resist the tendency of centrifugal force to throw it off.
4. As little tendency as possible to congeal, harden, crack or become brittle when used under lower temperature conditions; or, to carbonize and chip if exposed to abnormally high temperatures.



Courtesy of Fawcus Machine Co.

Fig. 18.—A set of steel mill gears completely enclosed in a cast iron casing. Bath lubrication by means of a high viscosity straight mineral gear lubricant is very satisfactory under such conditions.

To reduce wear, noise, misalignment of parts, rusting, stripped teeth, vibration, etc., it is absolutely essential that the above requirements be given consideration. Too, we must usually go into the matter from the viewpoint of their relative importance depending, of course, on the type of gear, mode of operation and whether or not automatic or bath lubrication is practicable.

Pressure is generally one of the chief points requiring consideration in a gear installation. As a rule tooth pressures will be high, and the bearing surfaces, due to their relatively small areas of contact, will carry heavy loads. The more carefully and accurately the gears have been cut the more intense will be these pressures, inasmuch as line contacts will practically exist under such conditions. Furthermore this line of contact or pressure will be constantly changing as the gear teeth mesh with each other. This will, of course, change the direction of application of the load.

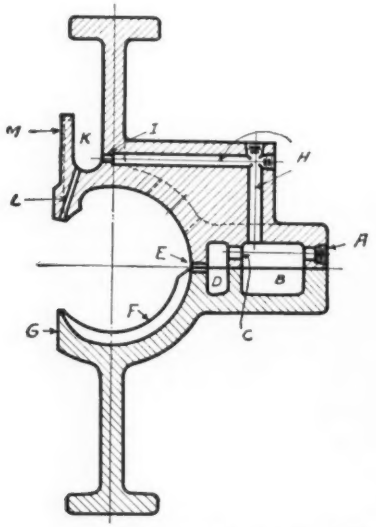
As long as rolling motion predominates the effect of the above on the structure of the teeth will not be serious. But once wear has begun to take place, sliding motion will supplant rolling motion to a proportional extent and grinding of the surfaces will result. This explains the more or less rapidity with which gear teeth will become worn down wherever their lubrication is neglected.

To meet the requirements as brought out heretofore, considerable attention has been devoted to the preparation of gear compounds by the oil industry. In general these will vary all the way from fluid mineral oils to the numerous preparations of the nature of grease, or other artificially thickened products containing talc, rosin, etc. The ultimate object is, in practically every case, to meet viscosity requirements. Non-lubricating fillers will make this possible but they oftentimes reduce the ultimate lubricating ability of the product to a marked extent. Therefore, they should be guarded against. In addition, lubricants so contaminated will lack to an appreciable degree the adhesive characteristics which may so often be of vital necessity. As a result when they are used under exposed conditions, on high speed gears, subjected perhaps to the detrimental effect of water, acids or alkalies, the gear teeth may suffer materially due to the inability of these lubricants to resist the effect of centrifugal force, the washing action of water or the corrosive effects of certain chemicals, etc.

So a straight mineral product should be used wherever possible. With the exception of steam turbine reduction gears, and elsewhere involving both gear and bearing lubrication, the viscosity of a gear lubricant should be relatively high. In other words it should vary from perhaps 100 seconds to 5000 seconds Saybolt at 210° Fahrenheit. This is a wide range, but we are confronted with a wide range of operating conditions, and construc-

tional requirements. Properly classified in accordance with the types of gears involved the viscosity range will fall within reasonable limits.

In connection with this matter of selection of gear lubricants a word as to greases will be



Courtesy of Westinghouse Electric & Mfg. Co.

Fig. 19.—Section of a pinion oiling system. Oil is admitted to the frame through a flexible oil connection from the housing. The oil flows into passage B, which extends for the full length of the frame, supplying oil to the pinion bearings and sprays. Under clockwise rotation, oil passes to the lower pan via openings C, D and E. For counter clockwise rotation oil passes from B via passageways H and I to the upper pan K. F indicates a number of ribs located between each hole E to prevent oil from being swept to one end of the pan by the helical teeth of the pinion. Bearings also receive their oil from passage B, at the same level as the holes E. As a result in event of faulty lubrication bearings will be the last to lose their oil, since the pinion spray passages C, etc., are located at a higher level than outlets E.

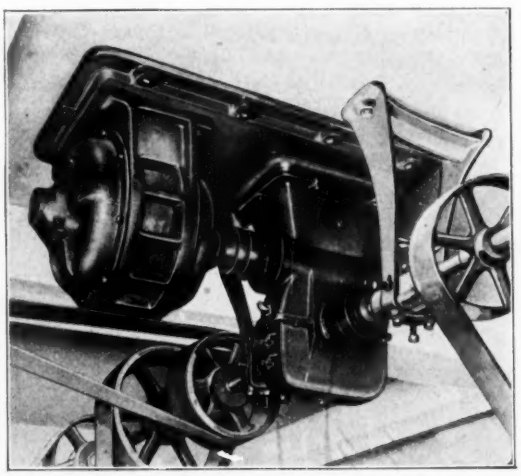
pertinent. Broadly speaking greases as a whole should only be used as gear lubricants under special conditions, due to their lack of adhesion and their tendency to squeeze out from between the teeth, leaving an imperfect lubricating film. It must be remembered that from a lubricating point of view greases are only as good as the mineral oil which they contain. Their soap content is merely a carrier, to give the requisite body or viscosity to the resultant product. Soap does not lubricate to any material extent, though it may serve as a cushion provided tooth pressures are not too high.

Greases are applicable as gear lubricants wherever their characteristics will meet the pressure and temperature condition prevalent. In certain cases they are suited to automotive service where relatively light-bodied products such as liquid greases may be required and where an oil-tight case is available. Here the gears run in a bath of the lubricant which will generally be of a semi-fluid nature. Greases are also advantageous on smaller gears, such as are so frequently employed on textile machinery, printing presses, etc. Such gears frequently cannot be bath lubricated due to the manner in which they are housed or guarded. Furthermore it is essential to use as few lubricants as possible throughout the plant and these must be capable of being readily removed from the product in event of contact therewith. Usually they are applied by hand on such gears.

METHODS OF GEAR LUBRICATION

In the application of gear lubricants the method employed will as a rule depend upon the type of service involved, the location, and function of the gears. We have stated that automotive transmission and differential gears can be bath lubricated by fluid greases; in contrast, where smaller trains of gears are used in the front end of our automobile engine, they will usually be pressure lubricated directly from the lubricating system of the engine. On the other hand steel mill gears, rubber roll drives and other larger installations will be frequently hand lubricated, a relatively heavy, viscous, straight mineral residual product being preferred due to its adhesive characteristics.

As a result, commensurate with the wide variety of conditions involved, gear lubrication and lubricants can rightfully be regarded as a most varied proposition. In fact in very many instances, special consideration will be necessary according to the size and number of gears, their location in the machine, the provisions (if any) for automatic lubrication, and



Courtesy of The Cleveland Worm & Gear Company.

Fig. 20.—View of worm reduction gear casing, showing the driving motor as well as the driven element or line shaft and pulleys. The compactness of such an installation is a feature. In this case the worm is located above the gear.

the nature of the products being handled. Where these latter are fragile or perishable as would be textile goods, paper, bread, or flour, their protection may relegate the attainment of theoretically correct lubrication to a subsidiary position. Elsewhere, as in the steel

Courtesy of Fawcus Machine Company

Fig. 21.—A grain elevator herringbone gear drive. Note manner of casing to prevent entry of grain, etc. Here a straight mineral gear lubricant has been found to effectively serve the gears and roller bearings, grease being used on the respective shafts.

mill, the protection of gears is paramount, for any occurrence of abnormal wear on the teeth may often materially affect the other wearing elements. Here conditions will often impose a most exacting task on the gear lubricant, for temperatures will be intense, pressures abnormal and of a decidedly fluctuating nature; too, water, salt and slag may all come into frequent contact with the gears, with the result that the lubricating film may be materially impaired. To meet hot water conditions, which are among the most serious problems in the steel mill, it is absolutely essential to use a gear lubricant of most tenacious characteristics. Essentially this should consist of a straight mineral residual product of from 1000 to 2000 seconds Saybolt viscosity at 210° F., compounded with a product especially adapted to rendering it capable of resisting the washing action of hot water.

As a general rule gear lubrication can be grouped into five classifications or conditions which will be indicative of the matter in which it can be most effectively carried out, i. e.:

1. Where an oil-tight casing or housing is employed, the gears therein being capable of lubrication apart from their shaft bearings. This is in effect the most ideal condition for it makes possible the use of a lubricant of just the right viscosity to withstand such pressures and temperatures as may be involved. As a rule bath, pressure or splash lubrication will be applicable. Where the former is employed a somewhat heavier product will be necessary than where the lubricant is forced or splashed onto the teeth under a certain amount of pressure. With a force feed system the oil is usually delivered to the teeth just before they pass into mesh.
2. In many cases, however, the gears will be so enclosed, but in addition their bearings will have to be lubricated by the same lubricant. Here a compromise must be made, just as in the case of reduction geared turbine lubrication. In other words a product sufficiently fluid to serve the bearings and yet viscous and adhesive enough to maintain a satisfactory film on the gear teeth will be necessary. Under such conditions a viscosity of approximately 60 to 200 seconds Saybolt at 210° F. will serve the purpose. Worm reduction gears are typical examples of the above. Here ball or roller bearings frequently present another point for consideration, wherever they are contained within the case. Naturally

Courtesy of Machinery.

Fig. 22.—Method of applying gear lubricant to a vertical worm gear drive.

as light a lubricant as possible should be used under such conditions.

3. But all gears are not encased, as has been noted. Frequently they will be entirely exposed, as are the gears on certain hoisting and excavating ma-

chinery. Here the lubricant must usually be applied by hand. So a highly viscous product will be necessary. As a rule a viscosity of from 1000 to 5000 seconds Saybolt at 210° F. will best resist the effects of weather, centrifugal force, and the usual dusty or dirty conditions which may be involved. Too, it will remain the longest on the teeth, thereby requiring but relatively infrequent renewals.

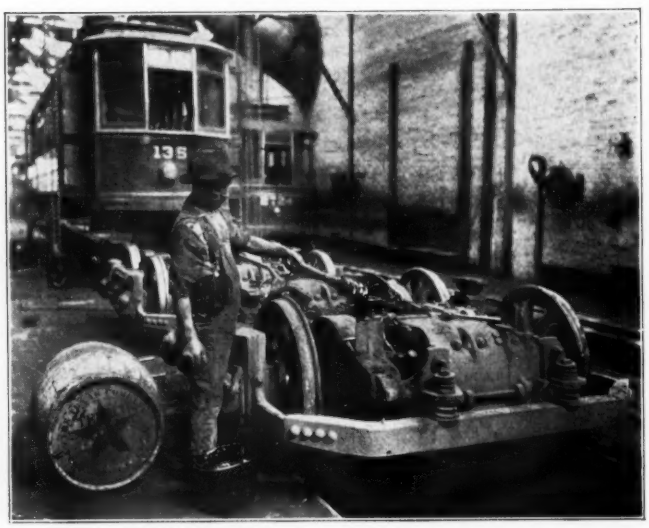


Fig. 23.—Method of applying lubricant to the gears of a trolley car, via the opening in the top of the gear case.

4. In other instances, exposed gears will operate with their lower portion partially enclosed in an oil tight pan which will permit of bath lubrication. This affords relatively automatic lubrication, though, of course it is necessary to keep the level of the lubricant as low as possible to prevent splashing or throwing especially if the gears run at higher speed. Usually good practice dictates that the lowermost teeth of the lower gear shall just dip into the lubricant, provided, of course, that the latter is of the requisite viscosity and tenacity to adhere sufficiently to the teeth to be carried, and in turn distributed to the teeth of such other gears as may be involved in these trains. Under slower speed conditions a lubricant of about 200 seconds Saybolt viscosity will meet these requirements. Where speeds are higher, however, or temperatures excessive, it may be advisable to use a heavier product, of about 1000 seconds Saybolt viscosity at 210° F.
5. The final classification may be taken as covering cases of entirely exposed gearing where dirt and other foreign matter may preclude effective lubrication, however, carefully the problem be analyzed. Gears on certain types of clay-working machinery are a good example of such a condition. Here the best we can do is seek for a lubricant which will stick, and yet not be so viscous as to ball up when contaminated with dust or dirt, etc. A straight mineral product of from 1000 to 2000 seconds Saybolt viscosity of 210° F. will, as a rule, give the most satisfactory results.

CONCLUSION

While considerable attention has been devoted to the grades of lubricants best suited for the several types of gears and their operating conditions, the fact must not be overlooked that the actual application of these products is of decided importance if they are to function at their best. It is not enough to just flood a gear case or pan, or to slop the heavier grades of gear compounds onto the teeth (and perhaps all adjacent mechanisms) with a paddle. Too much may prove to be a detriment from a power consumption point of view, just as too little may involve wear and increase friction. Just enough to lubricate effectively and give the requisite film on the teeth is the ideal. It is possible of attainment, although it may require more care and attention, but in the long run it will pay,—reduced power bills and repair costs have proven this.

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